



CARLO GAVAZZI SPACE SpA

# AMS02-TCS

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## 1. SCOPE

This document corresponds to contract deliverable DEL 073.

This document defines the requirements for the AMS-02 Cryo-cooler Thermal Control System (CRYO TCS), which is a part of the AMS thermal control system in order to transfer waste heat of the AMS Stirling Coolers to the dedicated Zenith radiators.

The requirements have been derived from:

- Specifications of AMS Stirling Coolers, which needs to be cooled by the LHP systems
- AMS-02 thermal requirements and Interface definition

CRYO TCS requirements are classified as follows:

- Applicable System Requirements
- Functional and Performance Requirements
- Lifetime and Reliability Requirements
- Design Requirements
- Resources
- Interface Requirements
- Environmental Requirements
- Assembly , Integration and Testing Requirements

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## 2. DOCUMENTS

### 2.1 APPLICABLE DOCUMENTS

AD	Doc.Number	Issue/Date	Rev.	Title/Applicability
1	AMS-552-SPEC-001	January 20 <sup>th</sup> 2006	C	Thermal requirements for the Interface between the Cryocooler and the External Thermal Control System
2	<sup>1</sup> JSC-28792	March 2005	D	AMS-02 Structural Verification Plan for the Space Transportation System and the International Space Station.
3	JSC-29202	March 2005	C	Experiment/Vacuum Case Payload Integration Hardware Interface
4	DC-IPC-2007-062	\	\	Capitolato Tecnico "Progetto: AMS Attività di fase C/D" Doc. N. DC-IPC-2007-062
5	DC-IPC-2007-063	\	A	Tailoring di primo livello delle norme ECSS, serie M-E-Q – Progetto AMS attività di fase C/D
6	DC-IPC-2007-064	\	A	Product Assurance Requirements - Progetto AMS attività di fase C/D

### 2.2 REFERENCE DOCUMENTS

RD	Doc.Number	Issue/Date	Rev.	Title/Applicability
1	AMS02-RQ-CGS-001	May 2007	\	AMS02 Thermal Requirements and Interface Definition
2	JSC-63164	21st September 2005	\	Quality Management Plan for the Alpha Magnetic Spectrometer 02 (AMS-02) Experiment
3	CTSD-SH-1782	9/30/2005	\	Multi-Layer Insulation for the Alpha Magnetic Spectrometer Guidelines
4	JSC-29095	06/01/2002	A	Experiment/Payload Integration Hardware Interfaces - Part I
5	JSC-29095	August 2004	A	Experiment/Payload Integration Hardware Interfaces - Part II
6	SSP 57003	17/06/03	B	Attached Payload Interface Requirements Document
	SSP 57004	13/06/03	B	Attached Payload Hardware Interface Control Document
	JSC-49978	2006	\	Phase II Flight Safety Data Package for the Alpha Magnetic Spectrometer - 02 (AMS-02)
	JSC-63123	28th November 2005		Alpha Magnetic Spectrometer – 02 Assembly and Testing Integration Plan

<sup>1</sup> SVP (Structural Verification Plan) for AMS can be found at <http://ams-02project.isc.nasa.gov/Documents/AMS-02%20SVP%20Rev%20E.pdf>

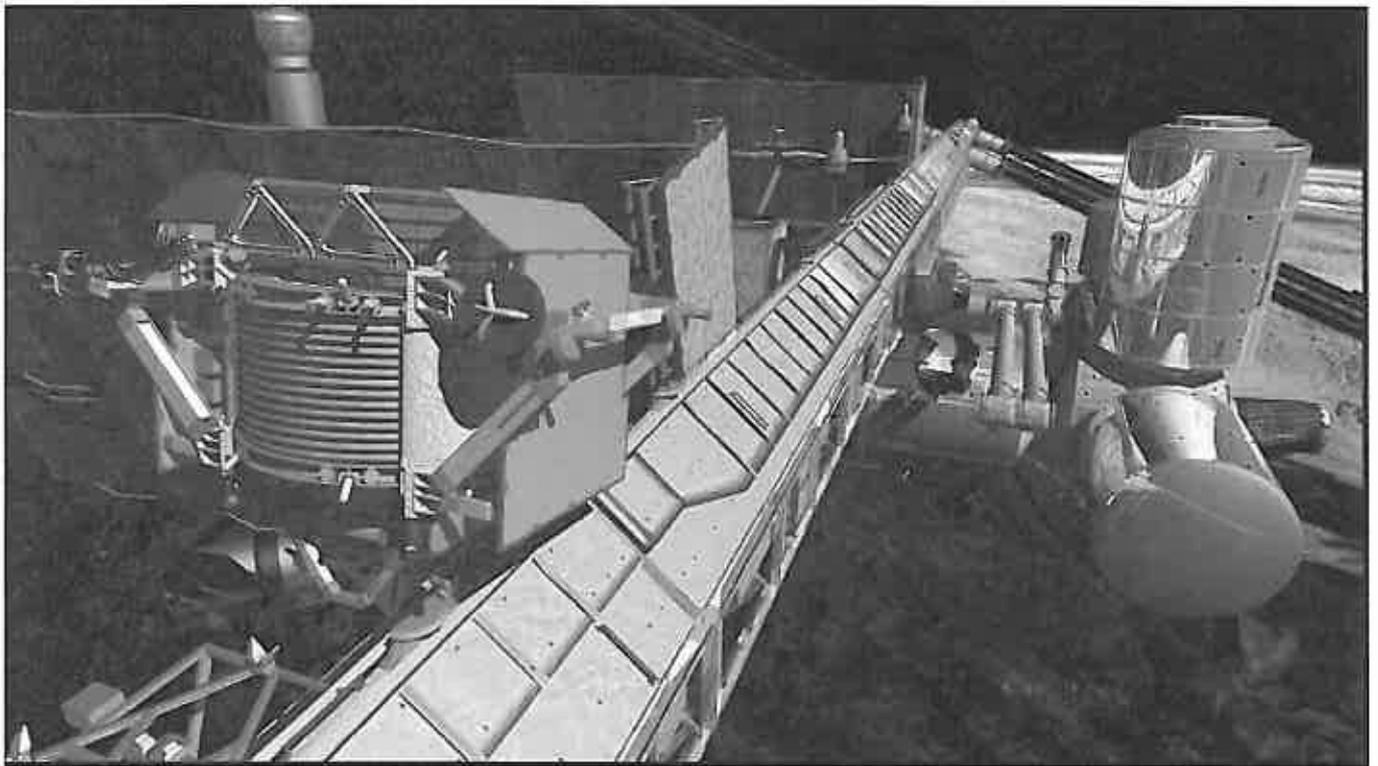
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## 2.3 SYSTEM DEFINITION

### 2.3.1 MISSION AND AMS SYSTEM DESCRIPTION

The international Alpha Magnetic Spectrometer experiment, AMS is a particle detector for high-energy cosmic rays. The scientific goal is to detect anti-matter and dark matter. For this reason several detectors and sub-detectors operate in a magnetic field, which is generated by a super-conductive Helium-cooled magnet.

The experiment is designated AMS-02, since it is an improved version of AMS-01 flown on the Shuttle mission STS-91. AMS-02 is planned for a five years mission as attached payload on ISS. The experiment is located on the ISS Truss structure as indicated in Fig. 2-1.



*Fig. 2-1 AMS attached to the ISS Truss Structure*

The overall experiment configuration is depicted in Figure 2-2 and Figure 2-3.

AMS includes 4 Stirling Cryogenic Coolers (Cryo-Coolers), which extract parasitic heat from one of the thermal protection shields, which are located around the Helium cooled AMS magnet.

Two of the Cryo-Coolers are located on opposite locations at the upper rim of the cylindrical Cryomagnet Assembly. The remaining two are located in a similar manner at the lower rim. The two pairs are rotated to each other by about 90°. One of the upper-rim coolers is depicted in Figure 2-2 and Figure 2-3 (designated with "CRYOCOOLER").



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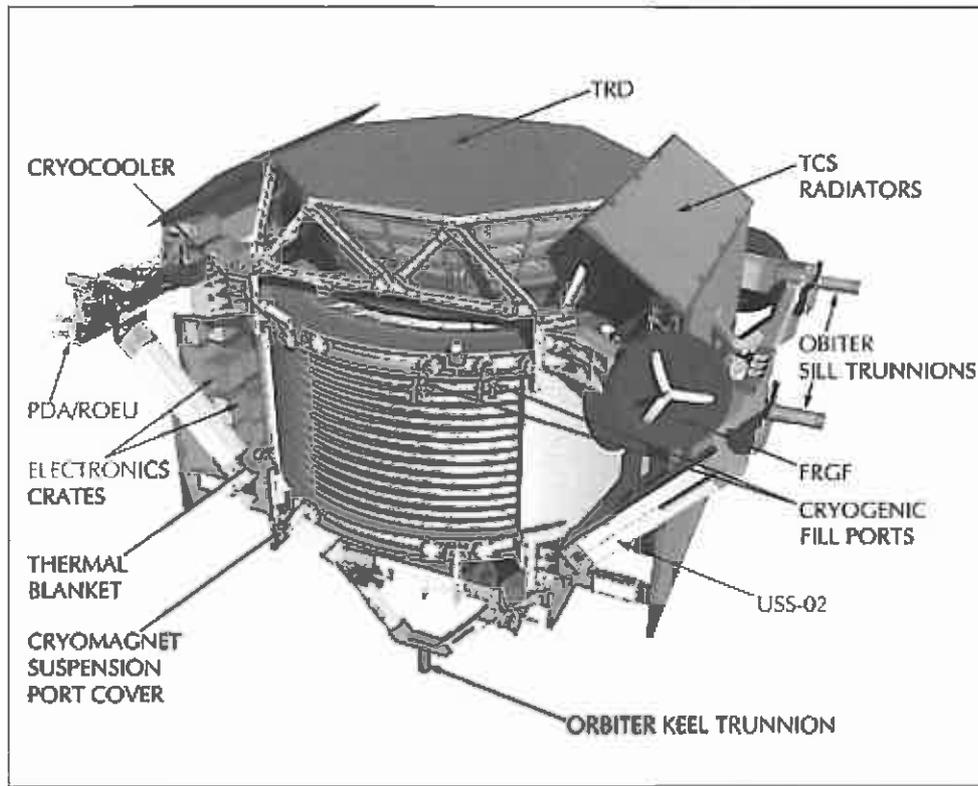


Fig. 2-2 Overall Configuration of AMS-02 (1)

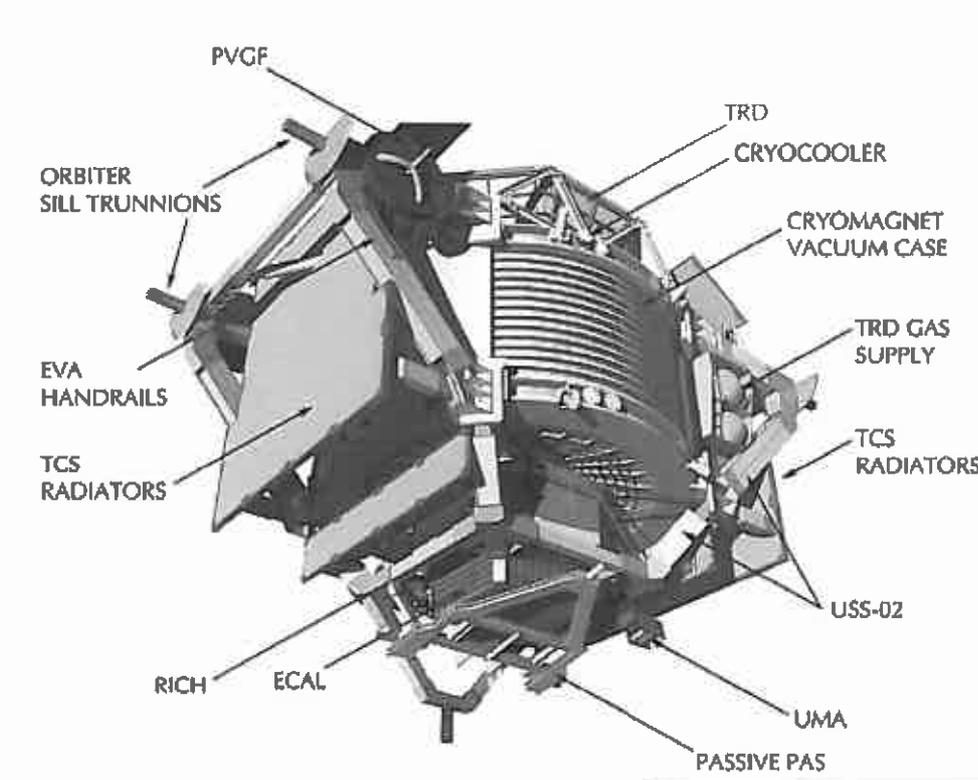


Fig. 2-3 Overall Configuration of AMS-02 (2)

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### 2.3.2 DESCRIPTION OF CRYO THERMAL CONTROL SYSTEM

Cryocoolers TCS consists of 4 zenith radiators, each designed to reject heat (up to 150 watts) transported via two Loop Heat Pipes (LHPs) bolted to one Cryocooler.



Fig. 2-4 Single zenith radiator panel + 2 LHPs (for reference)

The selected working fluid for the CRYO TCS is propylene to cope with the freezing issue. This is solved since the propylene freezing temperature is much lower than the ammonia freezing temperature (typical working fluid used in LHPs).

In addition the LHPs shall be equipped with a Passive valve to avoid rapid cryo cooler cooling down during power interruption. AMS will experience power interruptions while on ISS up to 3 times per year, 8 hours per event.

The CRYO TCS contains four separate LHP-systems, which can not be separated into units at lower integration level.

Each LHP-system consists of:

- Two LHPs
- One radiator sub-panel

Resulting in total 8 LHPs.

The four Zenith radiators sub-panels have identical configurations including identical condenser lay out

The four LHP systems can be divided into:

- Two identical LHP-systems serving the two Cryo-Coolers at the lower Cryomagnet Assembly rim. These

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systems have longer fluid lines and are designated "Long LHP System"

- Two identical LHP-systems serving the two Cryo-Coolers at the upper Cryomagnet Assembly rim. These have shorter fluid lines and are designated "Short LHP System"

Except for the different length of fluid line, the Long and Short LHP Systems have different sizes of the compensation chamber. But all LHP Systems have identical mechanical interfaces to the Cryo-Cooler.

The heat carrier is Propylene (Purity  $\geq 99.95\%$ ).

The LHPs are mounted on the warm part of the cryo-coolers to transfer this heat (plus up to 5 Watt heat lift in nominal operation) to the Zenith radiators, which are located on top the TRD (see Fig. 2-2 and Fig. 2-3 for TRD location). The Evaporators bodies of the LHPs are attached on opposite sides of the Cryo-Cooler "collar".

The actual evaporator consists of a stainless steel tube with an internal wick structure. A stainless steel reservoir is integrated for accommodating the working fluid. The evaporator is inserted and soldered into an aluminium alloy block, which is bolted to the mentioned cooler collars. Due to the low freezing point of Propylene, a passive control valve (base-line) which is made of stainless steel is added to the evaporator outlet, which controls the cryocooler to a predetermined minimum operating temperature by preventing the vapor to reach to the LHP condenser/radiators (either with a bypass line or with a ON/OFF valve).

The transport lines, which are supported by a structure rod, are routed on a more or less direct path to the radiators. LHP condensers lines are integrated into the radiator (direct condensing radiator). The overall shape of the four radiators is octagonal and matches the octagon shape of the upper TRD panel. The total available radiator surface has been divided in four equal radiator sub-panels, which are structurally independent from each other.

Fig. 2-4 depicts the overview of the thermal control system for AMS-02 Cryocoolers.

For functionality reasons of the AMS experiment, the face sheets of the radiator sub-panels as well as the condenser tubes attached to the inside of top face sheet need to be from aluminum alloy.

The rest of the LHP System may consist from different materials as long as other requirements are met (especially material compatibility, reliability and operational lifetime). In particular the other pipes (i.e. not in the radiator) can be stainless steel.

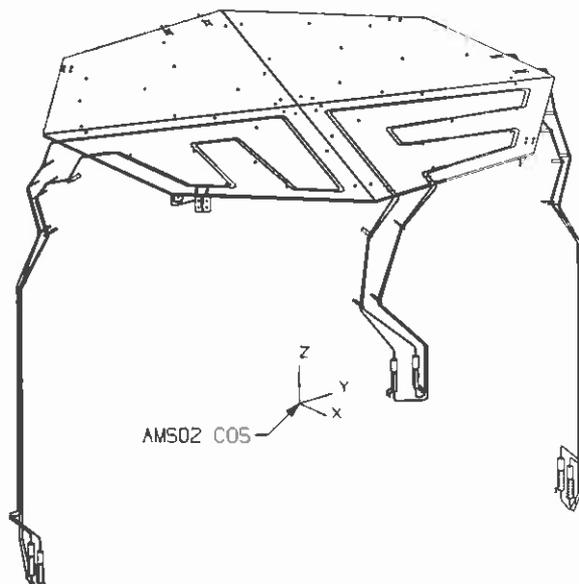


Fig. 2-5 Overview of Cryocooler Thermal Control System (only for reference)

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In addition to the CRYO TCS this specification covers the requirements of the CRYO TCS support beams.

The three support beams have three main different tasks: support TTCS ,Cryo TCS transport lines and magnet plumbing.

The following picture presents two out of three support beams. The beams run vertically. The TTCS tubing depart from the TTCSB , go up and down twice and finally reach the top part of the beam. Each beam shall have to support 10 TTCS tubes.



*Fig. 2-6 Overview of the two WAKE vertical support beams (only for reference)*

The left beam (out of the two presented) serves also as a support for the transport lines of one of the two cryo coolers that are mounted on the lower rim of the vacuum case. The cryo-coolers sitting on the top outer ring of the vacuum case don't have their TCS tubing running on the vertical beams.

The other (the third one) support beam is located in the opposite side (i.e. RAM side) wrt. the first two as presented in the following picture.

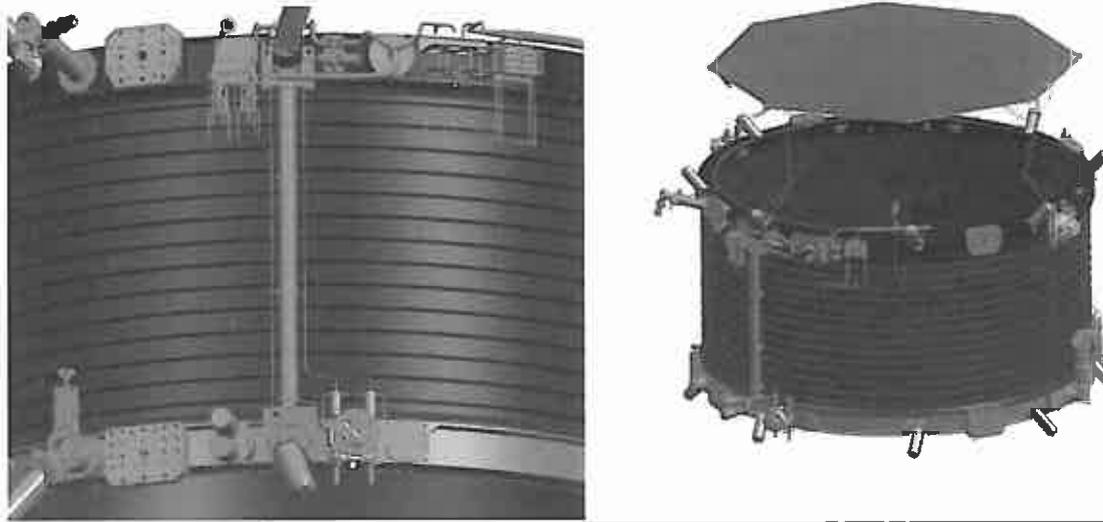


Fig. 2-7 Overview of the third vertical support beam (located at RAM side of AMS) (only for reference)

This beam serves to support the tubing of the second lower vacuum case rim mounted LHP cryo cooler. No TTCS tubing is supposed to run over this beam.

In addition to TTCS and CRYO TCS tubing , the three beams have to support magnet piping.

The following table summarizes the vertical support beams whose requirements are covered by this specification.

<u>VERTICAL SUPPORT BEAM</u>	<u>TTCS TUBING</u>	<u>CRYO TCS TUBING</u>	<u>MAGNET TUBING</u>
#1 (WAKE-STARBOARD)	√		
#2 (RAM)		√	
#3 (WAKE-PORT)	√	√	√

Table 2-1 Vertical support beams summary table

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## 2.4 VERIFICATION METHODS

If not stated explicitly otherwise, each of the requirements in this specification shall be verified by a combination of, but at least by one of the following methods:

- Review of Design (ROD)  
Review of technical layout, functional descriptions, drawings and schematics.
- Analysis  
Thermal and structural analysis, etc.
- Test  
Environmental tests, performance tests, etc.
- Inspection  
H/W inspection, integration inspection, process inspection, etc.
- Similarity  
Similarity with similar qualifications or applications

*The Verification of all the requirements, given in this specification, has to be documented. Any deviations has to be approved by CGS.*

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### 3. CRYO THERMAL CONTROL SYSTEM REQUIREMENTS

This set of requirements applies to the CRYO Thermal Control System.

The CRYO TCS is composed by 4 LHP systems. Each LHP system is made of 2 LHPs and 1 Zenith Radiator.

#### 3.1 TEMPERATURE REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-3.1-010	Min. and Max. , switch-on Cryo-cooler Operational/Non operational Temperatures	<p>The CRYO TCS shall keep the cryo-coolers within all the following temperature limit range while exposed to the extreme environmental ambient conditions:</p> <p>Minimum turn-on and operational temperature of the Cryo-Cooler: -30°C</p> <p>Minimum non-operational and survival temperature of the Cryo-Cooler: -40°C</p> <p>Maximum non-operational and survival temperature: +40°C</p> <p>Maximum operational at the cryocooler interface: +40°C</p>	Analysis	<p>In deriving corresponding cryo-cooler temperatures the resistance across the LHP Evaporator interface has been taken into account.</p> <p>Measured resistance (GSFC source) is 5.5 W/K across the interface, using indium foil.</p> <p>The temperature requirements are applied to the Cryo cooler Interface collar.</p> <p>These temperature requirements are associated to Cryo coolers own temperature sensors.</p>
AMS-CRYO-TCS-3.1-020	Temperature sensors	<p>The CRYO TCS shall be equipped with temperature sensors located on the Zenith Radiator.</p> <p>The temperature sensors shall be read-out by the Cryo Control Electronic Box (CCEB).</p>	ROD, Test	<p>There are no temperature requirements associated to these sensors. These sensors are used for on-orbit evaluation of the correct behaviour of the CRYO TCS system.</p>

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### 3.2 ENVIRONMENTAL REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-3.2-010	ISS orbit requirements	<p>The CRYO TCS shall be designed to meet requirements of typical ISS low earth orbit.</p> <p>Where the main parameters of the ISS orbit are:            Inclination: 51.6°            Nominal Altitude: 400 km            Orbit period: 90 – 93 min</p>	Similarity	Applicable to LHP supplier
AMS-CRYO-TCS-3.2-020	Radiation	<p>The CRYO TCS shall sustain the total dose of radiation equal to 1 krad/year without degradation of performance.</p>	Similarity	Applicable to LHP supplier
AMS-CRYO-TCS-3.2-030	Pressure	<p>The CRYO TCS shall withstand the following external pressure conditions:</p> <ul style="list-style-type: none"> <li>● inside transport container (if used) and inside integration and launch side preparation facilities: ambient + 1 mbar</li> <li>● during storage: ambient</li> <li>● during launch: 1E5 Pa to 1 Pa within 80 s during ascent</li> <li>● in orbit: vacuum of 1E-7 Pa over its lifetime</li> </ul>	ROD	Applicable to LHP supplier
AMS-CRYO-TCS-3.2-040	Load factor and frequency limits definition	<p>The CRYO TCS design load factors definition and frequency limits are based on the AD [2]</p>	ROD	
AMS-CRYO-TCS-3.2-050	Frequency Verification	<p>The CRYO TCS shall be verified by analysis if their fixed interface frequency is analytically predicted above fifty (50) Hertz and by test if the analytical frequency is below fifty (50) Hertz.</p>	Analysis	



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Req. Id. N.	Requirement	Description	Verification methods	Remarks												
AMS-CRYO-TCS-3.2 -060	Design limit load factors	<p>The CRYO TCS is an AMS02 secondary structure. For design and analysis purpose the design limit load factors ,listed in the following table, shall be applied:</p> <table border="1"> <thead> <tr> <th>Weight [lb]</th> <th>Load Factor [g]</th> </tr> </thead> <tbody> <tr> <td>&lt;20</td> <td>40</td> </tr> <tr> <td>20-50</td> <td>31</td> </tr> <tr> <td>50-100</td> <td>22</td> </tr> <tr> <td>100-200</td> <td>17</td> </tr> <tr> <td>200-500</td> <td>13</td> </tr> </tbody> </table> <p>These load factors include the effect of random vibration. These load factors shall be applied in any axis, with a load factor of twenty five percent of the primary load applied to the remaining two orthogonal axes, simultaneously.</p>	Weight [lb]	Load Factor [g]	<20	40	20-50	31	50-100	22	100-200	17	200-500	13	Analysis	
Weight [lb]	Load Factor [g]															
<20	40															
20-50	31															
50-100	22															
100-200	17															
200-500	13															
AMS-CRYO-TCS-3.2 -070	Acoustic load	<p>The Zenith Radiator panel is at the top of the AMS and it is exposed to acoustic excitation. Radiator panels are also potential acoustic receivers. The acoustic assessments performed to date (AD[2]) provide the load factors given in the following table:</p> <table border="1"> <thead> <tr> <th>Component</th> <th>Acoustic Load Factor [g]</th> </tr> </thead> <tbody> <tr> <td>Zenith Radiator</td> <td>12</td> </tr> </tbody> </table> <p>The CRYO TCS shall account for the acoustic loads by combining these load factors with the design limit load factors.</p>	Component	Acoustic Load Factor [g]	Zenith Radiator	12	Analysis									
Component	Acoustic Load Factor [g]															
Zenith Radiator	12															



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Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-3.2 -080	EVA load	An inadvertent kick/bump of 125 lbf, created by Extra-Vehicular Activities, shall be applied over a 1/2 inch diameter circular area perpendicular to the Zenith Radiator panel (Quasi-Static concentrated load). The Zenith Radiator side where the condenser lines are connected to transport lines shall be verified against EVA loads.	Analysis	
AMS-CRYO-TCS-3.2 -090	Thermal Induced load	The CRYO TCS system shall be verified under the worst cold conditions that occurs during a power outage.	Analysis	
AMS-CRYO-TCS-3.2 -110	Safety factors	The minimum factors of safety (FS) for structural component design of the CRYO TCS are 2.0 (ultimate) and 1.25 (yield) with no structural testing. For all the joints that do not have the matched drilled or reamed holes, a fitting factor of 1.15 shall be used for all modes of failure associated with structural joints, including bolts and bearing surfaces.	Analysis	
AMS-CRYO-TCS-3.2 -120	Structural Verification	The CRYO TCS (all the components and fastener) shall have MoS>0 under the applicable loads.	Analysis	

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Req. Id. N.	Requirement	Description	Verification methods	Remarks															
AMS-CRYO-TCS-3.2 -130	CRYO TCS thermal design dimensioning environment	The CRYO TCS thermal design shall be verified with Thermal Interface Data <sup>2</sup> provided by CGS for the following 2 dimensioning cases: - Worst HOT on ISS (on-orbit); - Worst COLD on ISS (on-orbit);	Analysis	Applicable to LHP supplier															
AMS-CRYO-TCS-3.2 -140	Orbit thermal parameter	The Thermal Interface Data set shall be generated on the basis of the following thermal environment : <table border="1" style="margin: 10px auto;"> <thead> <tr> <th></th> <th>HOT</th> <th>COLD</th> </tr> </thead> <tbody> <tr> <td>SOLAR [W/m<sup>2</sup>]</td> <td>1423</td> <td>1321</td> </tr> <tr> <td>ALBEDO</td> <td>0.4</td> <td>0.1</td> </tr> <tr> <td>EARTH [W/m<sup>2</sup>]</td> <td>286</td> <td>206</td> </tr> <tr> <td>ALTITUDE [mm]</td> <td>100</td> <td>270</td> </tr> </tbody> </table>		HOT	COLD	SOLAR [W/m <sup>2</sup> ]	1423	1321	ALBEDO	0.4	0.1	EARTH [W/m <sup>2</sup> ]	286	206	ALTITUDE [mm]	100	270	ROD	
	HOT	COLD																	
SOLAR [W/m <sup>2</sup> ]	1423	1321																	
ALBEDO	0.4	0.1																	
EARTH [W/m <sup>2</sup> ]	286	206																	
ALTITUDE [mm]	100	270																	
AMS-CRYO-TCS-3.2 -150	Cleanliness control	All the CRYO TCS parts shall be manufactured under cleanliness controlled conditions	ROD	Applicable to LHP supplier															

### 3.3 RESOURCES

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-3.3 -010	MASS	The total wet mass of the CRYO TCS shall not exceed 42,2kg, including brackets, spokes.	Analysis, ROD	MLI blankets are out of this budget. Their weight has to be included in a dedicate mass budget.

### 3.4 ASSEMBLY, INTEGRATION AND TESTING REQUIREMENTS

#### ASSEMBLY

<sup>2</sup> The Thermal Interface data (radiative set) shall be generated on the Zenith radiator external surface that acts as a sink for the LHP via the condenser lines.

The I/F data are composed by:

- Sink temperature (°C)
- Impinging orbital fluxes (divided in solar, albedo and planet IR) on Zenith relevant sides (W)
- Radiative links to sink temperature nodes (W/K4)

All the I/F data are time varying and are provided in SI units

The Thermal interface data set, provided on the basis of the orbital parameters defined above, are the result of an integrated thermal analysis with the ISS mathematical / geometrical models.

The selection of the dimensioning cases is based on a screening survey.

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Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-3.4 -010	CRYO TCS assembly	The CRYO TCS assembly shall be carried out by the LHP supplier.	ROD, Inspection	Applicable to LHP supplier

#### INTEGRATION

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-3.4 -020	CRYO TCS integration jig	The CRYO TCS Integration jig design shall be compatible with the Transportation jig design.	ROD	Applicable to LHP supplier

#### TESTING

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-3.4 -030	Proof Pressure test	Proof Pressure test shall be performed on the FM CRYO TCS	Test	Applicable to LHP supplier
AMS-CRYO-TCS-3.4 -040	Leak test	The FM CRYO TCS shall be leak tight and shall not experience a leak greater than ( $<1 \times 10^{-9}$ mbar x liter /sec)	Test	Applicable to LHP supplier
AMS-CRYO-TCS-3.4 -050	Vapor leak test	The FM CRYO TCS shall be subjected to a Vapor Leak Test after filling and pinching ( $<3 \times 10^{-8}$ Scc/s).	Test	Applicable to LHP supplier
AMS-CRYO-TCS-3.4 -060	Functional tests	<p>The FM CRYO TCS shall undergo a functional Performance Test under ambient conditions in the main orientations of the device under gravity:</p> <ol style="list-style-type: none"> <li>1) AMS in vertical position (AMS coordinate system - Z axis aligned with gravity vector)</li> <li>2) AMS in horizontal position (AMS coordinate system X axis parallel to gravity vector).</li> </ol>	Test	<p>Applicable to LHP supplier</p> <p>The LHP supplier standard procedure (to be proposed by the LHP supplier) shall be applied. Any deviation shall be agreed with CGS.</p>

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Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-3.4-070	Charged working fluid	The mass of the charged working fluid shall be measured	Test	Applicable to LHP supplier
AMS-CRYO-TCS-3.4-080	CRYO TCS system mass	The weight of all the CRYO TCS ready-to-fly parts shall be properly verified.	Test	Applicable to LHP supplier
AMS-CRYO-TCS-3.4-090	Inspection after test	The CRYO TCS shall be visual inspected after each test mode	Inspection	Applicable to LHP supplier

### 3.5 TRANSPORT REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-3.5-010	Transportation loads	CRYO TCS shall sustain following transportation loads, which occur between manufacturing/assembly and integration phases, without any loss of performance: <ul style="list-style-type: none"> <li>▪ Quasi static loads:  <math>X_a = +/-2g</math>,    <math>Y_a = +/-2g</math>,  <math>Z_a = +/-2g</math>,</li> </ul>	ROD	Applicable to LHP supplier
AMS-CRYO-TCS-3.5-020	CRYO TCS Transport Container	Each CRYO TCS Transport container shall be designed to accommodate 2 LHP systems (1 short and 1 long)	ROD	Applicable to LHP supplier

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## 4. LOOP HEAT PIPES SYSTEM REQUIREMENTS

This set of requirements applies to each single Loop Heat Pipe (LHP) and its main components.

### 4.1 LOOP HEAT PIPES REQUIREMENTS

#### 4.1.1 GENERAL REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-LHP-4.1.1-010	Product Assurance	All LHPs shall be designed, manufactured and verified according to the PA Plan of the LHP provider, which shall be approved by CGS at beginning of the contract.	ROD, Analysis, Inspection	<i>Exceptions can be tolerated from case to case after approval by CGS</i>  Applicable to LHP supplier

#### 4.1.2 FUNCTIONAL AND PERFORMANCE REQUIREMENTS

Regarding the temperature requirements, unless otherwise specified in the text, by "evaporator temperature" we shall consider the temperature of the interface of the evaporator to the cryo-cooler collar, on the evaporator side (i.e. evaporator saddle).

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-LHP-4.1.2-010	LHP system evaporator interface temperature requirement	The LHP system (=2 LHPs) shall keep the evaporator interface (saddle side) within the range $-30^{\circ}\text{C} - \frac{Q[\text{W}]}{11[\text{W}/^{\circ}\text{C}]}$ to $+40^{\circ}\text{C} - \frac{Q[\text{W}]}{11[\text{W}/^{\circ}\text{C}]}$ considering the cryo-cooler own dissipation Q (from 60 W to 150W)+ the heat lift (from 3 W to 8 W) under the hottest and coldest environmental conditions specified in AMS-CRYO-TCS-3.2 -130.	Analysis	Applicable to LHP supplier
AMS-CRYO-LHP-4.1.2-020	LHP evaporator interface temperature requirement Under Contingency operations/singl	To take into account either the failure of a LHP or a LHP not starting, <u>each LHP</u> shall keep the evaporator interface (saddle side) within the range $-30^{\circ}\text{C} - \frac{Q[\text{W}]}{5.5[\text{W}/^{\circ}\text{C}]}$ to	Analysis	Applicable to LHP supplier



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Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-4.1.2 -080	LHP Temperature Reference Point	The LHP Temperature Reference Point (TRP) shall be defined in the Evaporator assembly ICD	ROD	Applicable to LHP supplier

#### 4.1.3 LIFETIME AND RELIABILITY REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-4.1.3 -010	Lifetime	The design of the LHPs shall be compatible with a lifetime of 3 (+2) years in orbit and a storage time of 3 years on ground after final Flight Readiness Review (FRR).	Similarity	Applicable to LHP supplier
AMS-CRYO-TCS-4.1.3 -020	Reliability	Each LHP shall have a known reliability for in-orbit lifetime of 3 (+2) years. A reasonable value (>0.9) will be provided by the LHP provider.	Similarity	Applicable to LHP supplier

#### 4.1.4 DESIGN REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-4.1.4 - 010	LHP Design	LHPs shall be designed according to the IF drawings presented in Annex A and Annex B. The LHP transport lines design shall be based on CGS routing.	ROD	Applicable to LHP supplier
AMS-CRYO-TCS-4.1.4 - 020	LHP component materials	<p>The LHP shall be made of the following materials :</p> <p>Stainless Steel for the evaporator block (including evaporator body, compensation chamber, valve &amp; transport lines).</p> <p>Nickel for the wick.</p> <p>Aluminum alloy (AlMgSi0.5 or equivalent) for condenser tubing</p>	ROD	<p>Applicable to LHP supplier</p> <p>Bimetallic joints are designed and provided by CGS.</p>



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Req. Id. N.	Requirement	Description	Verification methods	Remarks
		integrated into the radiator face sheet and Evaporator saddle.  (Al Alloy —Stainless steel) for bimetallic joints between condenser tubes and transport lines.  Propylene(Purity≥99.95%) as heat carrier.		
AMS-CRYO-TCS-4.1.4 - 030	LHP Declared Material List	All the LHP parts materials shall be properly recorded in the Declared Material List.	ROD	Applicable to LHP supplier
AMS-CRYO-TCS-4.1.4 - 040	Nickel mass estimate	The precise mass estimate of Nickel content shall be provided by the LHP provider, within 5% accuracy.	ROD	Applicable to LHP supplier
AMS-CRYO-TCS-4.1.4 - 050	Material and manufacturing process selection	The selection of the LHP materials and manufacturing process shall be such as to avoid material compatibility and structural problems in order to meet the required LHP performance over the specified life time.	ROD	Applicable to LHP supplier
AMS-CRYO-TCS-4.1.4 - 060	LHP manufacturing process CoC	All the LHP manufacturing processes used in the LHP parts shall be covered by standard specification (i.e. ECSS, NASA, MIL, etc..) or by LHP supplier internal specification in line with the required standards. These specifications shall include methods of inspection, tests and acceptance/rejection criteria.	ROD	Applicable to LHP supplier
AMS-CRYO-TCS-4.1.4 - 070	Weld inspection data	Inspection data shall be provided for all the individual welds , showing that they are compliant to the applicable process specification requirements.	ROD	Applicable to LHP supplier



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Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-4.1.4 - 080	Surface Treatment	<p>The LHP parts manufactured from aluminum alloy (i.e. condenser lines, evaporator saddle) shall have the following surface treatment:</p> <p>(ALODINE 1200) according to Mil-C- 5541 Class 3 or equivalent, unless bonding processes require a different treatment (e.g.: anodic coating, sand-blasting)</p> <p>The surface treatments of the LHP parts manufactured from a different material shall be according to applicable standards of space industry and agreed by CGS.</p>	ROD	Applicable to LHP supplier
AMS-CRYO-TCS-4.1.4 - 090	Maximum Design Pressure	All the 8 LHPs shall be designed for an internal Maximum Design Pressure (MDP), which is equal to the vapor pressure of the working fluid at Maximum Design Temperature (MDT) <sup>3</sup> .	Analysis	Applicable to LHP supplier
AMS-CRYO-TCS-4.1.4 - 100	Proof pressure definition	The LHPs FM proof pressure shall be equal to 1.5xMDP	ROD	Applicable to LHP supplier
AMS-CRYO-TCS-3.1.4 -110	Burst pressure definition	The LHP burst pressure shall be $P \geq 4xMDP$	ROD	<p>The LHP design shall be verified to the burst pressure (see relevant requirements in the test section)</p> <p>Deformations are accepted.</p> <p>Applicable to LHP supplier</p>

<sup>3</sup> The MDT is calculated under the hottest environmental conditions specified in section AMS-CRYO-TCS-3.2 -130, considering two failures and the maximum load applied (cryo-cooler dissipation)



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Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-3.1.4 -120	By-pass Valve	Each LHP shall be equipped with a passive by-pass valve for the vapor phase of the heat carrier.	ROD	Applicable to LHP supplier
AMS-CRYO-TCS-3.1.4 -130	By-pass Valve set-point	The by-pass valve shall prevent the vapor to reach the radiator at a set-point temperature of -20°C	ROD	Applicable to LHP supplier
AMS-CRYO-TCS-3.1.4 -140	Valve set point, EOL	The valve set point in End Of Life (EOL) conditions (due to Argon vessel partial depletion), shall be determined (according to the measured leak rate) considering 3 (+2) years life-time.	Analysis	Applicable to LHP supplier
AMS-CRYO-TCS-3.1.4 -150	LHP bonding	The LHP shall have a mechanically secure electrical conducting connection to a conductive structure (Class S Bonding ) as specified in SSP-30245	ROD, Test	
AMS-CRYO-TCS-3.1.4 -160	Flight heritage	The LHP supplier shall notify CGS on mechanical load levels the Loop heat Pipe have seen during qualification or similar missions.	ROD	Applicable to LHP supplier

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## 4.1.5 RESOURCES

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-4.1.5-010	MASS	The total wet mass of each LHP shall not exceed 830 grams, including Evaporator assembly (evaporator body, aluminum saddle, compensation chamber, valve and bypass line if applicable), transport lines, condenser tubes (including the glue if they are bonded to the radiator), heaters, thermostats.	Analysis , Test (End mass verification of flight LHP by weighing).	Fasteners are excluded from this budget.  Applicable to LHP supplier
AMS-CRYO-TCS-4.1.5-020	POWER	The power available at each LHP heater shall not exceed 10W @113 Vdc.	ROD	Applicable to LHP supplier

## 4.1.6 INTERFACE REQUIREMENTS

### 4.1.6.1 MECHANICAL INTERFACE REQUIREMENTS

The LHP evaporator saddle mounting surface represents the mechanical interface of the LHP with the Cryo-cooler equipment.

The LHP condenser lines mounting surface represent the mechanical interfaces with the Zenith Radiator.

The LHP transport lines lateral brackets mounting surface represent the mechanical interfaces with the Vertical Support Beams and the Zenith Radiator.

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-4.1.6.1-010	CRYO-COOLER / LHP MECHANICAL INTERFACE	The LHP evaporator saddle shall be designed according to the Cryo-cooler mechanical Interface as per drawing in ANNEX B. The mechanical interface shall be identical for each LHP.	ROD	Applicable to LHP supplier
AMS-CRYO-TCS-4.1.6.1-020	LHP / START-UP HEATER MECHANICAL INTERFACE	The LHP shall be designed to accommodate start-up heaters. The mechanical accommodation shall prevent the heater from debonding in case the power density limit is exceeded (e.g. heater can be secured by a metallic plate).	ROD	Heaters and relevant provisions shall be delivered by CGS.  Applicable to LHP supplier



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Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-4.1.6.1 -030	LHP / ZENITH RADIATOR MECHANICAL INTERFACE	The LHP condenser lines shall be designed according to the Zenith Radiator condenser line pattern [ANNEX A].	ROD	
AMS-CRYO-TCS-4.1.6.1 -040	LHP/VSB MECHANICAL INTERFACE	The LHP transport lines shall be supported by brackets bolted down to Vertical Support Beams (VSBs).	ROD	
AMS-CRYO-TCS-4.1.6.1 -050	LHP bimetallic joint mechanical Interface	The bimetallic joints shall be supported by brackets.	ROD	The bimetallic junction design and procurement is under CGS responsibility.

**4.1.6.2 ELECTRICAL INTERFACE REQUIREMENTS**

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-4.1.6.2 -010	Start-up heater Power Allocation	Each LHP start-up heater shall not exceed 10W power allocation @ 113VDC	ROD	
AMS-CRYO-TCS-4.1.6.2 -020	Heater Voltage	The start-up heaters shall operate and be compatible with the 120Vdc steady state voltage range of 106Vdc to 126.5Vdc.	ROD	
AMS-CRYO-TCS-4.1.6.2 -030	Heater Connector	The start-up heater shall be supplied by Power Distribution System (PDS) via a bracketed connector mounted on the cryo-cooler assembly.	ROD	

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#### 4.1.6.3 THERMAL INTERFACE REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-4.1.6.3-010	LHP condenser lines / Zenith Radiator contact conductance	The attachment method selected to bond the condenser lines to the Zenith radiator skin shall provide a thermal contact conductance greater than 5 W/K per condenser tube meter length	Analysis	
AMS-CRYO-TCS-4.1.6.3-020	Thermal protection	Each LHP system shall be properly insulated from the external environment.	Analysis, Test	

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#### 4.1.7 TESTING AND INSPECTION REQUIREMENTS

The following test requirements shall apply at the LHP component level.

It is expected that the vibration transmitted through the primary structure (USS) to the AMS02 components will be smaller than Minimum Workmanship Levels (MWL). For mission success purpose the AD[2] recommends that vibration testing of the critical components shall be performed to MWL.

The LHP components have been reviewed under this light and the by-pass valve (actually the valve bellow) has been identified to be the only critical part. For this reason vibrations test at MWL levels (or even higher) shall be part of the valves qualification test campaign.

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-4.1.7 -010	Welding inspections	All the LHP weld junctions shall be He leak inspected.	Test	Any additional weld joint inspection (e.g. X-ray inspection) shall be agreed with CGS case by case.  Applicable to LHP supplier
AMS-CRYO-TCS-4.1.7 -020	Burst tests	Burst Pressure Test shall be performed on samples from same material lot , in particular on: <ul style="list-style-type: none"> <li>• Bimetallic joint</li> <li>• Filling port pinching</li> <li>• Welding parts</li> <li>• Valve (both chambers).</li> </ul>	Test	The burst pressure test shall be performed with representative LHP parts, which are manufactured out of the same material lots as used for flight hardware. Configuration of the test sample shall be agreed with CGS (in particular for what concerns the welding points).  The burst pressure samples shall not experience any damage while subjected to the required burst pressure level(= 4xMDP). Permanent deformations are allowed.  Applicable to LHP supplier



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# AMS02-TCS

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Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-4.1.7 -030	Valve qualification campaign	<p>4 valves shall be subjected to the following qualification campaign:</p> <ul style="list-style-type: none"><li>- Performance</li><li>- Leakage</li><li>- Vibration</li><li>- Performance</li><li>- Leakage</li><li>- Fatigue</li></ul> <p>The valve set point and residual (Argon) leakage shall meet the specifications at the end of the test campaign.</p> <p>Test campaign shall be properly documented.</p>	Test	<p>Any deviation from this Qualification campaign shall be agreed with the CGS.</p> <p>Applicable to LHP supplier</p>
AMS-CRYO-TCS-4.1.7 -040	Valve fatigue cycles	<p>The valve shall be able to operate after being tested a number of cycles of 200000 (carried out in the sequence specified in the valve qualification campaign).</p>	Test	<p>Fatigue Cycles to be performed at full stroke, even if smaller movements are expected in flight.</p> <p>Applicable to LHP supplier</p>
AMS-CRYO-TCS-4.1.7 -050	Valve performance and characteristics curve	<p>Each FM Valve shall undergo performance tests to ensure that each valve operates properly at the defined set-point and Stroke vs. pressure shall be provided as a characteristics curve for each valve.</p>	Test	<p>Applicable to LHP supplier</p>
AMS-CRYO-TCS-4.1.7 -060	Valve Pressure test	<p>Each FM valve shall be tested at a proof Pressure of 1.5 x MDP</p>	Test	<p>Applicable to LHP supplier</p>



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Req. Id. N.	Requirement	Description	Verification methods	Remarks														
AMS-CRYO-TCS-4.1.7-070	Propylene residual flow through the valve in OFF mode	The LHP manufacturer shall provide the typical residual propylene flow to the radiator ("leakage") when the valve is in OFF mode (no vapour towards radiator).	Test	The thermal effects due to this residual flow shall be evaluated.  Applicable to LHP supplier														
AMS-CRYO-TCS-4.1.7-080	Valve assembly vibration levels	Each FM valve assembly shall withstand vibration levels (Minimum Workmanship Levels) as specified in the AD[2] and reported in the following table.	Similarity <sup>4</sup> , Analysis	Applicable to LHP supplier														
<p><b>Table 15-2: Minimum Workmanship Levels for the Alpha Magnetic Spectrometer - 02</b></p> <table border="1"> <tr> <td rowspan="5" style="text-align: center;">All Axes</td> <td style="text-align: center;">20 Hz</td> <td style="text-align: center;">0.01 g<sup>2</sup>/Hz</td> </tr> <tr> <td style="text-align: center;">20-80 Hz</td> <td style="text-align: center;">+3 dB/Octave</td> </tr> <tr> <td style="text-align: center;">80-500 Hz</td> <td style="text-align: center;">0.04 g<sup>2</sup>/Hz</td> </tr> <tr> <td style="text-align: center;">500-2000 Hz</td> <td style="text-align: center;">-3 dB/Octave</td> </tr> <tr> <td style="text-align: center;">2000 Hz</td> <td style="text-align: center;">0.01 g<sup>2</sup>/Hz</td> </tr> <tr> <td colspan="3" style="text-align: center;">Overall = 6.8 Gms</td> </tr> </table> <p><small>Note: MWL Test duration: 60 seconds per axis</small></p>					All Axes	20 Hz	0.01 g <sup>2</sup> /Hz	20-80 Hz	+3 dB/Octave	80-500 Hz	0.04 g <sup>2</sup> /Hz	500-2000 Hz	-3 dB/Octave	2000 Hz	0.01 g <sup>2</sup> /Hz	Overall = 6.8 Gms		
All Axes	20 Hz	0.01 g <sup>2</sup> /Hz																
	20-80 Hz	+3 dB/Octave																
	80-500 Hz	0.04 g <sup>2</sup> /Hz																
	500-2000 Hz	-3 dB/Octave																
	2000 Hz	0.01 g <sup>2</sup> /Hz																
Overall = 6.8 Gms																		
AMS-CRYO-TCS-4.1.7-090	Valve reservoir Argon leakage	The leakage of the Argon (or whatever fluid is used in the valve) towards ambient shall be experimentally evaluated.	Test	Applicable to LHP supplier														

<sup>4</sup> Similarity to the valve qualification test campaign

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## 4.2 ZENITH RADIATOR REQUIREMENTS

### 4.2.1 TEMPERATURE REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-4.2.1-010	Temperature Range	The Zenith radiator shall not experience any damage while subjected to the temperature range -130 °C / +60°C	ROD	
AMS-CRYO-TCS-4.2.1-020	Power-off cycles	The Zenith radiator shall not experience any damage while subjected to 3 AMS02 power-off cycles per year, 8 hours duration each, resulting in an total of 9 cycles (3 cycles/year * 3 years). The expected cooling rate is -1°C/min	ROD	
AMS-CRYO-TCS-4.2.1-030	Temperature Reference Point	The Zenith radiator Temperature Reference Point (TRP) shall be defined in the CRYO TCS ICD	ROD	

### 4.2.2 LIFETIME AND RELIABILITY REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-4.2.2-010	Lifetime	The design of the Zenith Radiator shall be compatible with a lifetime of 3 (+2) years in orbit and a storage time of five years on ground after final flight readiness acceptance.	Similarity	

### 4.2.3 DESIGN REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-4.2.3-010	Material, Mechanical parts and manufacturing process	The selection of Zenith Radiator materials, mechanical parts and manufacturing process shall be made following the guidelines of ECSS-Q-70B	ROD	
AMS-CRYO-TCS-4.2.3-020	Local Planarity (500x500mm)	The Zenith Radiator outer skin (radiative side) shall have a local	ROD, Test	

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Req. Id. N.	Requirement	Description	Verification methods	Remarks
		planarity less than 1mm. The Zenith Radiator inner skin (TRD side) shall have a local planarity less than 1mm.		
AMS-CRYO-TCS-4.2.3 -030	Total Planarity	The Zenith Radiator outer skin (radiative side) shall have a total planarity less than 1,5mm. The Zenith Radiator inner skin (TRD side) shall have a total planarity less than 2mm.	ROD, Test	

#### 4.2.4 INTERFACE REQUIREMENTS

##### 4.2.4.1 MECHANICAL INTERFACE REQUIREMENTS

The Upper Cover of the TRD detector represents the mechanical interface of the Zenith Radiator.  
The Zenith Radiator shall mechanically interface with the TRD upper cover by means of support brackets and pins.

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-4.2.4.1 -010	TRD/Zenith mechanical interface	The Zenith radiator support brackets shall be designed according to the TRD mechanical Interface as per ANNEX C	ROD	

##### 4.2.4.2 ELECTRICAL INTERFACE REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-4.2.4.2 -010	Zenith Radiator external bonding	The Zenith Radiator shall have a mechanically secure electrical conducting connection to a conductive structure (Class S Bonding ) as specified in SSP-30245. The Zenith Radiator shall use for	ROD	

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Req. Id. N.	Requirement	Description	Verification methods	Remarks
		bonding purposes the TRD upper bracket mounting plates as per drawing in ANNEX D.		
AMS-CRYO-TCS-4.2.4.2 -020	Zenith Radiator own bonding	The two skins of the Zenith Radiator shall be bond together (Class S Bonding ) as specified in SSP-30245.	ROD	

#### 4.2.4.3 THERMAL INTERFACE REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-4.2.4.3 -010	Radiative thermal coupling	The Zenith Radiator shall be properly insulated from the TRD upper cover by means of thermal blanket.	Analysis	

#### 4.2.5 TRANSPORT REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-4.2.5 -010	Transportation loads	All Zenith Radiators (x4) shall sustain following transportation loads, which occur between manufacturing and assembly, without any loss of performance: <ul style="list-style-type: none"> <li>▪ Quasi static loads:  <math>X_a = \pm 2g</math>,      <math>Y_a = \pm 2g</math>,  <math>Z_a = \pm 2g</math>,</li> </ul>	ROD	

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## 5. VERTICAL SUPPORT BEAMS REQUIREMENTS

### 5.1 DESIGN REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-5.1-010	TTCS tubing	The WAKE side VSBs shall be equipped with brackets to support the 10 TTCS tubes (each VSB).	ROD	
AMS-CRYO-TCS-5.1-020	TTCS tubing support brackets position	The position of the WAKE VSBs brackets to support the TTCS tubing shall be agreed with the TTCS team.	ROD	
AMS-CRYO-TCS-5.1-030	TTCS tubing support brackets hole diameter tolerance	The Hole diameter tolerance in the TTCS tubing support brackets shall be in a way to provide a clasping mechanical coupling.	ROD	
AMS-CRYO-TCS-5.1-040	LHP system tubing	The RAM and WAKE-PORT VSBs shall be equipped with brackets to support the 4 LHP tubes (each VSB).	ROD	
AMS-CRYO-TCS-5.1-050	LHP tubing support brackets hole diameter tolerance	The Hole diameter tolerance in the LHP tubing support brackets shall be in a way to provide a clasping mechanical coupling.	ROD	
AMS-CRYO-TCS-5.1-060	MAGNET tubing	The RAM VSB shall be equipped with brackets to support the Magnet tubes.	ROD	
AMS-CRYO-TCS-5.1-070	Open section and orientation	The VSB shall have an open section design and the section shall be oriented to the TTCB location to make the routing easier.	ROD	

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## 5.2 ENVIRONMENTAL REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-5.2 -010	VSB thermal deformation	The VSB design shall be able to withstand thermal deformation (e.g. sliding end fixation).	Analysis, ROD	
AMS-CRYO-TCS-5.2 -020	VSB thermal protection	The VSB shall be suitably insulated by thermal environment to protect the running tubes	ROD	

## 5.3 RESOURCES

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-5.3 -010	VSB Mass budget	The total mass of each VSB shall not exceed 2,5 Kg, including lateral , internal brackets for tubing support and fasteners.	Analysis , Test (End mass verification of flight parts by weighing).	

## 5.4 INTERFACE REQUIREMENTS

Req. Id. N.	Requirement	Description	Verification methods	Remarks
AMS-CRYO-TCS-5.4 -010	VSB mechanical Interface with VC	The VSB shall have a mechanical Interface compliant with the AD[3].	ROD	

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## 6. DELIVERABLES

### 6.1 DELIVERABLE H/W

The CRYO TCS hardware to be produced and delivered shall consists of **4 complete LHP systems** composed by:

Part	Quantity	Supplier	Remarks
Evaporator assy	8	LHP supplier	Including the saddle
Compensation chamber	8	LHP supplier	
Valve	8	LHP supplier	Including Argon
Transport lines	16	LHP supplier	
Bimetallic joint	16	CGS	
Start-up heaters	8	CGS	Specified by LHP supplier
Thermostats	8	CGS	Specified by CGS
Heater/Thermostat cabling	As needed	CGS	CGS is responsible for the cabling connecting the heater/thermostat circuit to the intermediate circular connector.
Zenith Radiator panel	4	CGS	
Zenith Radiator outer brackets (i.e. stiff brackets, Z-brackets)	4 Stiff brackets 4 Z-brackets	CGS	
Zenith Radiator spokes	56	CGS	
Zenith Radiator coating	As needed to cover the Radiator surface	CGS	Specified by CGS
Working fluid	As needed to fill the loops	LHP supplier	Propylene
MLI blanket	As needed	CGS	
Temperature sensors	12+12 (TBC)	CGS	The number is under discussion with CCEB read-out system responsible.
Temperature sensor connector (MDTD)	4	CGS	
Temperature sensor cabling	As needed	CGS	CGS is responsible for the cabling part connecting the temperature sensors to the intermediate connector.
Bracket fasteners	As needed	CGS	
Bonding straps	As designed	CGS	
Transportation Jig	2	LHP supplier	
Integration Jig	1	CGS	
Transport container	1	LHP supplier	1 Transport container shall transport 2 LHP systems (1 long and 1 short)

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Thermal Filler	8 foils	GSFC	Indium foil is the designed thermal filler
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*Table 6-1 Deliverable H/W items*

The CRYO TCS supports hardware to be produced and delivered shall consists of **3 complete Vertical Support Beams, including LHP/TTCS/Magnet tubing support brackets.**

## 6.2 DELIVERABLE DOCUMENTS

Part	Supplier	Remarks
<b>Declared Material, Component, Parts and Process List</b>	LHP supplier / CGS	
<b>LHP system Certificate Of Conformance</b>	LHP supplier	The LHP supplier shall provide Certificates of Conformance for each LHP system for: <ul style="list-style-type: none"> <li>• Purity of Propylene</li> <li>• Filling quantity (According to fill analysis)</li> <li>• Successful acceptance pressure and leak test</li> <li>• Successful burst pressure on selected components</li> <li>• Mass measurement of the LHP parts according to estimated mass budget</li> <li>• Welding and manufacturing processes</li> </ul>
<b>Pa Plan</b>	LHP supplier	
<b>Valve qualification test report</b>	LHP supplier	The qualification campaign of the valve shall be properly documented
<b>Acceptance test plan and procedures</b>	LHP supplier	
<b>Test Report</b>	LHP supplier	All the requirements that are supposed to be verified by test shall be properly documented.
<b>Inspection reports</b>	LHP supplier/CGS	
<b>Mass measurement</b>	LHP supplier / CGS	
<b>Management documentation</b>	LHP supplier	<ul style="list-style-type: none"> <li>- Minutes of Meeting.</li> <li>- Progress Report (bi-monthly) including:               <ul style="list-style-type: none"> <li>o Action Item Status List.</li> <li>o Master Bar Chart.</li> <li>o NCR List</li> <li>o Shipment Announcement.</li> </ul> </li> </ul>



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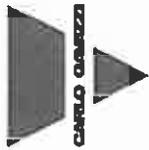
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<b>CRYO LHP thermal analysis report</b>	LHP supplier	
<b>CRYO LHP design report</b>	LHP supplier	
<b>CRYO TCS thermal analysis report</b>	CGS	
<b>CRYO TCS design report</b>	CGS	
<b>CRYO LHP manufacturing dossier</b>	LHP supplier	
<b>CRYO TCS manufacturing dossier</b>	CGS	
<b>CRYO TCS handling, Transportation and Storage procedures</b>	LHP supplier	
<b>CRYO LHP user manual</b>	LHP supplier	
<b>CRYO TCS user manual</b>	CGS	
<b>CRYO TCS Integration procedure</b>	CGS	
<b>CRYO TCS structural analysis report</b>	CGS	
<b>CRYO LHP ICD</b>	LHP supplier	
<b>CRYO TCS ICD</b>	CGS	
<b>CRYO LHP 3D Model</b>	LHP supplier	Step format
<b>CRYO TCS 3D Model</b>	CGS	Step format
<b>CRYO LHP End Item Data Package</b>	LHP supplier	
<b>CRYO TCS End Item Data Package</b>	CGS	

Table 6-2 Deliverable documentation







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## ANNEX C. TRD UPPER COVER ICD

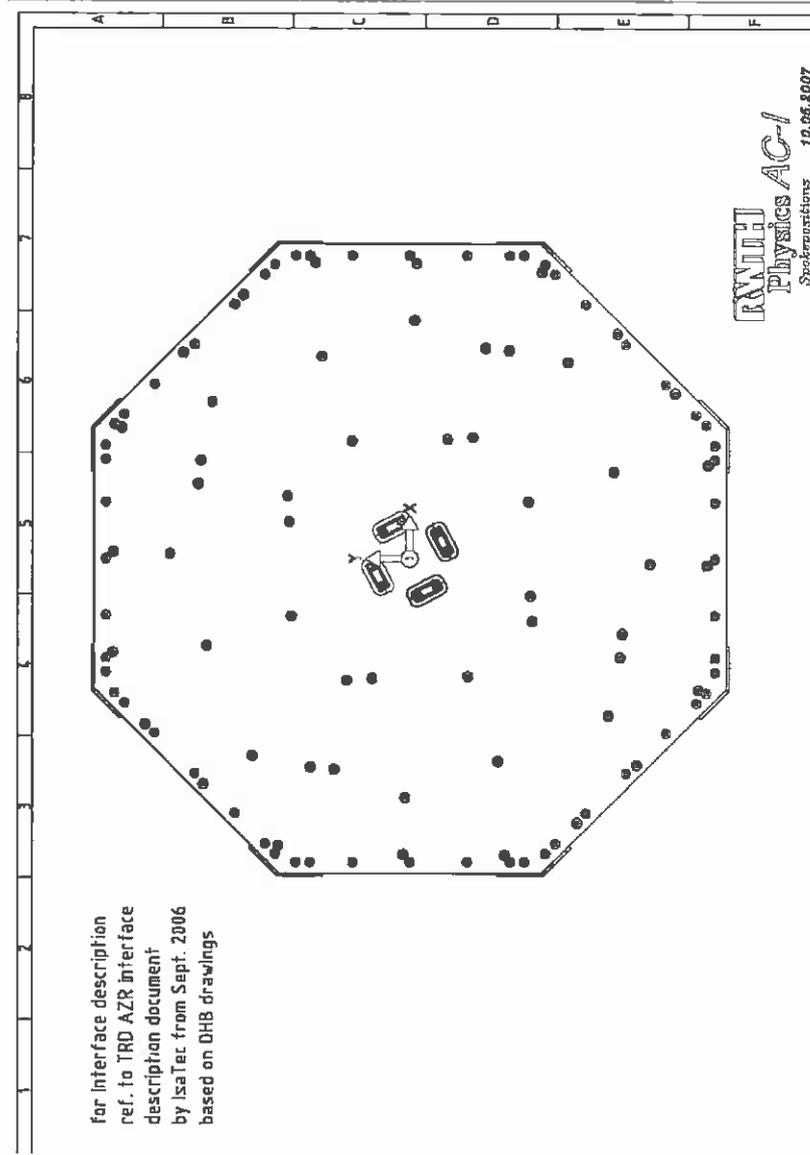
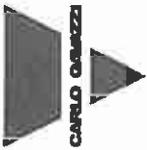


Figure C-1. TRD Upper Cover Interface Control Drawing (just for reference)



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**ANNEX D. ZENITH RADIATOR BONDING INTERFACE**

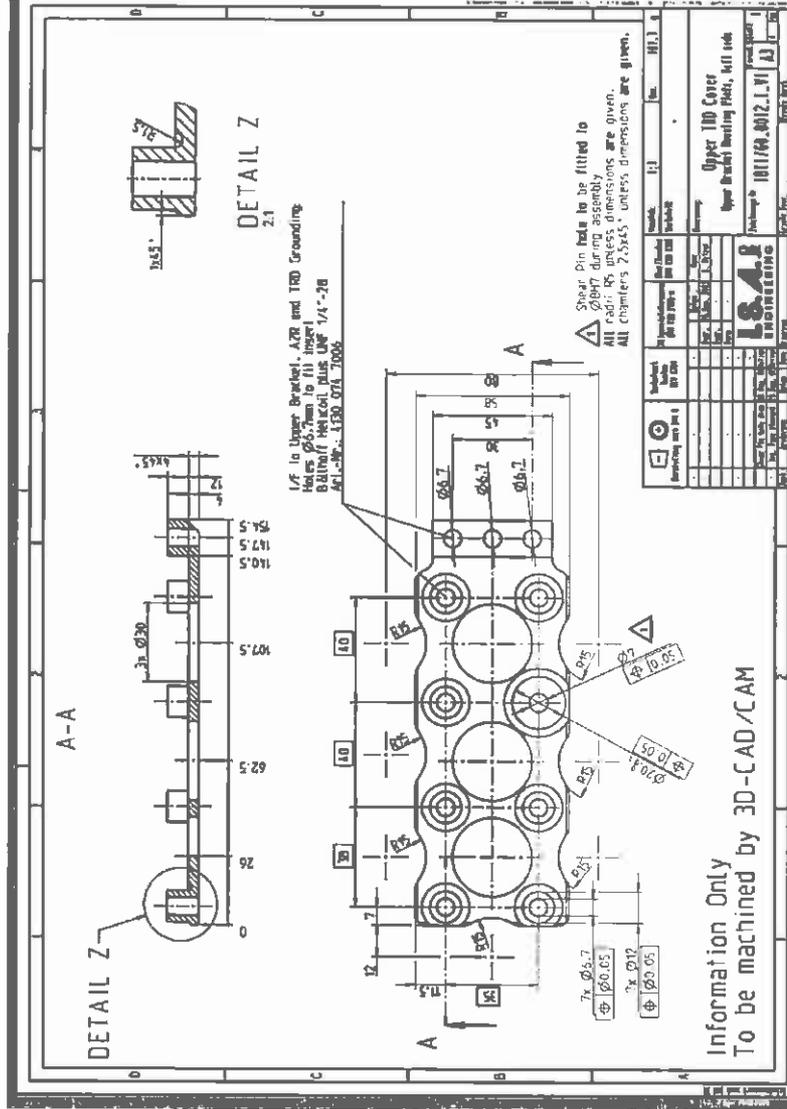


Figure D-1. TRD Upper Bracket Interface for Zenith radiator Bonding

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